

### III. ENVIRONMENTAL DATA AND ENGINEERING CONTROLS

#### Environmental Data

In an extensive study, reported in 1963, of pyrolysis of furfuryl alcohol and furfuryl alcohol-filler resins [39], the off-gases produced between 150 and 850 C (302 and 1,562 F) were both qualitatively and quantitatively analyzed at 50 C (122 F) intervals. No trace of furfuryl alcohol could be found by gas chromatography or mass spectrometry.

In a NIOSH survey [24] of health hazards in a foundry using no-bake resins in the production of cores and molds, area and personal samples were taken for formaldehyde, furfuryl alcohol, isopropyl alcohol, and free silica. The base resin contained furan, furfuryl alcohol, and some urea-formaldehyde resins. Furfuryl alcohol samples, collected on charcoal tubes, showed that the coremakers were exposed at a TWA level of 6.25 ppm (25 mg/cu m), whereas the other workers were exposed at below the 5-ppm (20 mg/cu m) level. In the 10 samples collected, furfuryl alcohol concentrations up to 16.5 ppm (66 mg/cu m) were found.

A similar foundry survey [23], reported in 1973, also involved the use of no-bake resin systems composed of paraformaldehyde and furfuryl alcohol and catalyzed by phosphoric and sulfuric acids. Breathing zone and area samples were collected during the coremaking operation and during the coremaking-curing operation. The concentration of furfuryl alcohol rose to 8.6 ppm (34.4 mg/cu m) during the core preparation cycle (15 minutes) and remained at 2.2 ppm (8.8 mg/cu m) during the full core production cycle (1 hour). During the core preparation cycle (15 minutes), if the sand used was warm, the furfuryl alcohol concentration rose to 10.8 ppm (43.2 mg/cu m); when the sand was hot, it rose to 15.8 ppm (63.2 mg/cu m). Formaldehyde concentrations of 0.33 ppm (0.4 mg/cu m) were also found from the samples collected during the latter process.

A series of 24 air samples was taken during 4 months in 1976 at a plant producing furfuryl alcohol [40]. Only one sample had 0.2 ppm (0.8 mg/cu m) furfuryl alcohol; the rest showed less than 0.1 ppm (0.4 mg/cu m). On February 15, 1978, four air samples were collected in another furfuryl alcohol plant. The average furfuryl alcohol concentration was 0.3 ppm (range 0.2-0.4 ppm).

In 1976, Virtamo and Tossavainen [41] reported the results of a study carried out at 10 iron and steel foundries in Finland that used furan resins as binding agents for sand, mainly in coremaking. These furan binders were copolymers of furfuryl alcohol (containing 50-95% furfuryl alcohol) with either urea-formaldehyde or phenol-formaldehyde resins. The urea-furan resins were used in iron founding, and the phenol-furan resins

were used in steel founding. The unhardened resin produced gases that included furfuryl alcohol, formaldehyde, and possibly small amounts of phenol. The exothermic hardening reaction increased the evaporation rates of these compounds, and, therefore, the concentrations of their airborne compounds. The concentrations of these airborne gases were measured in the coremaking areas. From a total of 36 furfuryl alcohol and 43 formaldehyde samples examined, the arithmetic means of the concentrations of the airborne gases were 4.3 ppm (17.2 mg/cu m) for furfuryl alcohol (range 0.15-40 ppm; 0.6-160 mg/cu m) and 2.7 ppm (3.32 mg/cu m) for formaldehyde (range 0.15-20 ppm; 0.19-24.6 mg/cu m). As a result, 22% of the furfuryl alcohol determinations and 38% of the formaldehyde determinations exceeded their established permissible limits in Finland (5 ppm or 20 mg/cu m for furfuryl alcohol and 2 ppm or 2.46 mg/cu m for formaldehyde).

### Sampling and Analytical Methods

#### (a) Sampling

Furfuryl alcohol may be readily absorbed in water [42-45], glacial acetic acid [46], aqueous sodium hydroxide [47], or acetone [48]. Sampling can be performed by drawing contaminated air through a collecting device at a measured flowrate that is low enough to ensure complete absorption of the contaminant, ie, the slower the sampling rate, the higher the absorption efficiency should be in any specific system.

Furfuryl alcohol can be sampled in at least three kinds of absorbers that use liquid collection media. Simple gas washing bottles, such as midget impingers, may be used, but, since the degree and duration of contact between the sampled air and the liquid are not maximized, it may be necessary to use two or more of these absorbers in series in order to achieve maximum collection efficiency. Simple gas washing bottles have the advantage of being simply constructed and easy to clean, and they require only a small volume of liquid. The spiral or helical absorber can also be used for organic vapor collection. Although it is larger and contains more liquid than a gas washing bottle, its chief advantage is a higher collection efficiency because of the longer contact path between the sampled air and the collection liquid. Fritted bubblers provide high collection efficiency because of the extensive gas-liquid contact and the low flowrate used (0.5-1.0 liters/minute), but do not have the advantage of small size and volume and ease of cleaning.

Collection of furfuryl alcohol vapor in liquid allows a wide variety of analytical techniques such as oxidation by bromine, polarography, or UV spectrophotometry. However, the use of a liquid impinger for collection of breathing zone samples is at least inconvenient. Successful use of collectors containing liquids requires careful handling of glassware during collection and shipment of samples to avoid breakage and spillage.

Another method of collecting nonreactive vapors such as furfuryl alcohol is by the use of solid adsorbents such as silica gel or activated charcoal. Because of its polar nature, silica gel attracts polar substances, such as water. Alcohols are easily collected on silica gel but may be displaced if samples are collected under humid conditions. The volume of air sampled may have to be limited under these conditions in order to minimize loss. The nonpolarity of activated charcoal enables it to adsorb most organic vapors and gases in preference to atmospheric moisture, permitting long sampling times. The reliability of charcoal sampling depends on the efficiency of desorption of furfuryl alcohol from the charcoal. Greinke [49] tested a number of solvents and found that acetone gave the best recovery of furfuryl alcohol from charcoal, about 85%; with carbon disulfide, only about 50% was recovered. Pyridine has recently been found to permit desorption of furfuryl alcohol from charcoal with desorption efficiencies approaching 100% [46]. Porapak Q has been studied recently [50] as an adsorbent for furfuryl alcohol vapor. This medium is not composed of highly polar molecules and thus does not strongly adsorb highly polar molecules such as water or formaldehyde. When acetone is used, furfuryl alcohol can be desorbed from Porapak Q with recoveries greater than 91% and with a coefficient of variation of 0.033 [50]. Acetone will also desorb impurities that are sometimes present in the Porapak Q, so the sorbent may need to be washed in acetone and dried prior to sampling [50].

Sampling by absorption of furfuryl alcohol on Porapak Q is the preferred method. This method has the advantage of minimal interference from airborne moisture and polar organic vapors such as formaldehyde. In addition, desorption of furfuryl alcohol from Porapak Q is efficient and reproducible without the disadvantages of using pyridine, the odor of which is highly objectionable.

#### (b) Analysis

Furfuryl alcohol collected in liquid media can be analyzed by UV spectrophotometry, polarography, or oxidation by bromine. Aqueous scrubber samples have been analyzed for furfuryl alcohol by measuring the absorbance at 217 nm [44]. The limit of detection for this method was below 0.8 mg/cu m for a 25-liter air sample collected in 20 ml of water at 1-3 liters/minute. However, other substances, such as phenol, formaldehyde, and furfural, which also absorb in the region of 217 nm and are usually present in the air with furfuryl alcohol, will interfere. In a 1971 report, Pfaffli [45] described an analytical method by which furfuryl alcohol could be determined without interference from phenol, formaldehyde, or furfural. The analysis was based on the opening of the furan ring in the presence of dilute acid. By adding methanol, polymerization was prevented and reaction of the open ring with hydrazine was permitted, yielding a cyclic hydrazone that absorbed strongly at 242 nm. With a 50-liter sample collected in 20 ml of water, the detection limit of this method of furfuryl alcohol analysis was estimated to be 0.4 mg/cu m.

Microgram quantities of furfuryl alcohol can also be determined polarographically after being collected in a fritted sampler containing water [42]. Air was sampled at 1 liter/minute for 3-6 minutes. The analysis was based on the oxidation of furfuryl alcohol to furoic acid by hexavalent chromium, the unconsumed quantity of which was determined polarographically. Up to 3 mg of furfural in the sample solution does not interfere with the analytical procedure.

An analytical method applicable to furfuryl alcohol, but not to furfural, is bromination to saturate the furan ring [51]. Potassium iodide was added to the brominated sample to permit subsequent titration of the liberated iodine. According to the authors, the overall error of this method is  $\pm 1\%$ , provided that the total furfural present in the sample does not exceed 20%. This method has been used to measure furfuryl alcohol in air after sampling at less than 1.5 liters/minute through a fritted bubbler containing glacial acetic acid [22,28].

Gas chromatography has become a prevalent method of detection and analysis of organic materials. This technique has been used in the occupational environment [52] in conjunction with sampling the breathing zone on a solid sorbent followed by carbon disulfide desorption. Pyridine, however, when used as a desorption solvent, has given excellent desorption efficiencies. This method has been used to evaluate worker exposure in furfuryl alcohol production facilities [46]. For a 10-liter sample, the lower detection limit of the method was 0.8 mg/cu m, but the authors calculated that by sampling 100 liters of air, this limit would be 0.08 mg/cu m.

Gas chromatography has also been tested with an adsorbent normally used as a column packing for gas chromatographs. In this method [50], furfuryl alcohol was collected in a glass tube containing Porapak Q and desorbed with acetone. Sampling 6 liters of air at 0.01-0.05 liters/minute, furfuryl alcohol concentrations of 120-470 mg/cu m can be detected. The relative standard deviation of the combined sampling and analytical method is 0.072. The sampling device has the advantages of being small, of containing no liquids, and of allowing efficient, reproducible desorption of furfuryl alcohol. This analytical method is selected as the method of choice because it is sensitive, rapid, subject to few interferences, and, in conjunction with the compatible sampling method selected, avoids the possibly hazardous use of carbon disulfide or highly objectionable pyridine. This method [50] has been validated by NIOSH. Details of the method are described in the appendix.

### Engineering Controls

In processes for the production, storage, and use of furfuryl alcohol, the application of chemical engineering principles, together with care in

selecting process equipment, particularly pumps and valves, are necessary to ensure that furfuryl alcohol is not released to the occupational or community environments [53]. The use of instrumentation and remote controls is recommended for monitoring processes, for allowing rapid and safe intervention into routine operations, and for emergencies that might develop from failures of the process or equipment. The use of closed systems to prevent release of materials from a process is generally recommended, but to maintain the integrity of such a system, an engineering control program, including frequent inspections, preventive maintenance, and prompt repair of leaks, is essential.

When closed systems are not practical or leaks develop, the probability of exposure to furfuryl alcohol in the occupational environment is increased. The likelihood of exposure also increases during operations that require handling, transferring, or sampling of raw materials of furfuryl alcohol products or wastes. Exposure may also occur during required maintenance or repair of equipment by entry into tanks, vessels, or other confined spaces or when an emergency or a nonroutine situation develops. Therefore, when furfuryl alcohol is handled in an open system, a ventilation system, such as a hood, glove box, or local exhaust system, may be necessary. In addition, a ventilation system is desirable as a standby if a closed system should fail. The principles set forth in Industrial Ventilation--A Manual of Recommended Practice [54] and Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.1-1971 [55], should be applied to control atmospheric concentrations and prevent the release of raw materials, furfuryl alcohol products, or wastes during those operations when exposure is possible.

To ensure effective operation of ventilation systems, routine inspection should include face velocity measurements of the collecting hood, examination of the air mover and collection or dispersion system, and measurements of atmospheric concentrations of furfuryl alcohol in the work environment. Any changes in the work operation, process, or equipment that may affect the ventilation system must be promptly evaluated to ensure that control measures provide adequate protection for employees. All facilities require frequent inspection and preventive maintenance to ensure that leaks are readily detected and repaired to avoid exposure of employees. Exhaust gases that may contain furfuryl alcohol or hazardous raw materials or wastes should be prevented from being released into the occupational and community environments.

#### IV. WORK PRACTICES

Undiluted furfuryl alcohol has a flashpoint of 75 C (167 F) [56]. It is therefore classified as a combustible liquid of Class IIIA by the rules in 29 CFR 1910.106. The lower and upper flammable limits in air at 72.5-122 C (162.5-251.6 F) are 1.8% (18,000 ppm) and 16.3% (163,000 ppm), respectively [2]. Furfuryl alcohol can therefore be handled safely at temperatures below its flashpoint. Nevertheless, as good practice, all ignition sources should be controlled in areas where furfuryl alcohol is processed, stored, manufactured, or otherwise used. In the event of a fire, foam, dry chemical, or carbon dioxide extinguishers or water should be used [57]. Firefighting personnel should be advised that the flames of burning alcohols are difficult to see in daylight and that extra care must be taken in fighting these fires [58].

The principal safety problem associated with furfuryl alcohol is its violent polymerization reaction when in contact with acids. Improper use or negligent handling and storage of furfuryl alcohol can result in explosive reactions [18,19,59]. Furfuryl alcohol should be stored in tightly closed containers in cool, well-ventilated areas away from all acids or heat sources. Containers should bear labels that contain information on the sensitivity of furfuryl alcohol to acids. In storage areas, signs conveying this caution should be posted in readily visible locations.

Where furfuryl alcohol is stored in tanks, the tanks should be diked to contain the tanks' volume, reducing the probability of runoff to areas where acids may be used or stored.

Protective clothing and safety glasses with side shields or chemical safety goggles should be worn by employees to reduce the possibility of skin absorption of, or eye irritation by, furfuryl alcohol, since animal data [26-28,31] indicate these to be hazards associated with exposure to furfuryl alcohol. The degree of protection required depends on the severity of the potential exposure. Eye protection should be used in any situation where liquid furfuryl alcohol may enter the eye. For jobs where there is the possibility of the body being soaked, face shields and full-body suits that are rubberized or otherwise resistant must be used. Under routine working conditions, however, regular long-sleeved work clothing should suffice for skin protection against small amounts of furfuryl alcohol. When exposure is limited to the handling of contaminated equipment or small amounts of furfuryl alcohol, rubberized gloves should afford adequate protection. Protective clothing and equipment should be decontaminated before reuse, and any apparel or equipment showing signs of deterioration should be discarded or repaired.

Compliance with the recommended exposure limit should protect workers against adverse effects from inhaled furfuryl alcohol. When respiratory devices are permitted, they must meet the specifications of Table I-1. A respiratory protection program in accordance with 29 CFR 1910.134 must be followed to ensure that respirators are routinely inspected and properly cleaned, maintained, and stored.

As a good practice, the employer should provide locker and changing facilities as well as showers, and should encourage workers to shower before they leave the workplace. Good personal hygiene can help avoid accidental eye or skin contact with furfuryl alcohol. Workers should wash thoroughly before eating, smoking, or drinking to prevent ingestion of furfuryl alcohol and to limit its inhalation.

The plant should establish contingency plans to meet any emergency that can reasonably be anticipated. Stations equipped with first-aid supplies, approved respiratory protective devices, protective garments, or other special equipment should be maintained at easily accessible locations. Eyewash fountains and emergency showers must be available and clearly marked in furfuryl alcohol work areas. In the event of eye contact with furfuryl alcohol, the affected area should be flushed with a copious flow of water followed by appropriate medical attention.

Standard procedures should be formulated for maintenance and repair of engineering control systems; these procedures should not depend on the use of respiratory protection. There are several essential elements in these maintenance procedures. Tanks, pumps, valves, or lines must be drained and thoroughly flushed with water or steam prior to repair activities, especially welding, grinding, or other operations that might offer an ignition source for flammable vapor or combustible liquid. All personnel entering confined spaces must be supplied with whole body protection, such as overalls or impermeable clothing, and suitable respiratory protection in accordance with Table I-1. Workers should wear this respiratory protective equipment unless prior measurements indicate that the air concentration of furfuryl alcohol is at or below the recommended TWA concentration limit and that there is an acceptable oxygen concentration (about 20%). A second properly protected worker must be on standby outside the confined space, and effective communication must be maintained between all involved persons. A safety harness and lifeline should be used.

Spilled furfuryl alcohol must be cleaned up immediately by properly trained, adequately protected personnel. Liquid can be sorbed with vermiculite, sand, or other suitable mineral aggregate and removed from the work area for disposal. If sufficient drainage to a suitable collection basin is available, spilled liquid may be hosed away with large quantities of water. When feasible, the area of the spill should be ventilated to remove any aerosol or vapor. Methods of disposal must comply with Federal, state, and local regulations.

Employee education on the safe handling of furfuryl alcohol and its hazards is essential. It is particularly important that employees be informed of the danger arising from contact of furfuryl alcohol with acids. This information and instructions informing employees of proper handling methods, cleanup procedures, personal protective equipment, and emergency procedures should be presented as part of a continuing education program as well as in written form. The NIOSH publication An Identification System for Occupationally Hazardous Materials [60] should be consulted in the design of written material describing the relevant physical, chemical, and toxicologic properties of furfuryl alcohol or of mixtures or formulations containing the compound.



## V. DEVELOPMENT OF STANDARD

### Basis for Previous Standards

In 1960, the American Conference of Governmental Industrial Hygienists (ACGIH) proposed a threshold limit value (TLV) of 50 ppm (200 mg/cu m) for furfuryl alcohol [61] expressed as a TWA concentration limit for an 8-hour day. In 1971, a tentative change to reduce the TLV to 5 ppm (20 mg/cu m) was proposed [62], and this value was adopted in 1974 [63]. The ACGIH did not give a reason for recommending a reduction of the TLV to 5 ppm from 50 ppm. No new evidence was presented [64]. It is reasonable to infer from comparing the documentations [62,63] that the change was made in order to reduce the likelihood of eye irritation.

In 1976, the ACGIH [65] also recommended a short-term exposure limit (STEL) of 40 mg/cu m for furfuryl alcohol. The STEL was defined by the ACGIH as an absolute ceiling not to be exceeded at any time during a 15-minute excursion period. It was proposed that no more than four excursions be permitted each day, with at least 60 minutes between excursions.

In 1976, the International Labour Office in Geneva [66] reported an established limit for furfuryl alcohol of 50 ppm (200 mg/cu m) in Australia, the Federal Republic of Germany, Rumania, and Yugoslavia, but 5 ppm (20 mg/cu m) in Belgium, Finland, and Sweden.

The current Federal limit is 50 ppm (200 mg/cu m) expressed as a TWA concentration for an 8-hour day [66]. This limit was based on the 1968 ACGIH recommendation.

### Basis for the Recommended Standard

#### (a) Permissible Exposure Limit

Furfuryl alcohol has been shown to be readily absorbed by inhalation, ingestion, or percutaneous application. The available toxicity information on furfuryl alcohol is largely on acute toxicity. Whether furfuryl alcohol can cause chronic toxicity is not clear from presently developed information. It may be that chronic injury does not occur, conceivably because of rapid detoxification or excretion. Incomplete information suggests this may be so, but investigations of furfuryl alcohol have been too limited to allow confidence on this point.

In rats, CNS depression leading to respiratory paralysis and death has been observed at furfuryl alcohol concentrations as low as 188 mg/cu m for

6 hours [27]. Identical exposure of mice and rabbits resulted in no effects. A monkey exposed to furfuryl alcohol vapor for 6 hours at 1,040 mg/cu m had only very slight lacrimation, but when exposed to 956 mg/cu m for 6 hours/day for 3 days, it showed no effects whatsoever.

The available exposure data do not indicate the furfuryl alcohol concentration below which there will be no adverse effects in workers. In humans, the only effects reported to be associated with exposure to furfuryl alcohol have been slight lacrimation [23], bronchitis, and mild sore throat [25]. In the case of lacrimation [23], it is not clear whether it was caused by formaldehyde, by furfuryl alcohol, or by the combined action of the two. The exposure concentrations associated with the respiratory irritation [25] are not known. Since the current Federal limit (200 mg/cu m for 8 hours) is about one-fifth the concentration that reportedly caused no effects in monkeys [27], this limit may be adequate to protect workers from adverse effects from furfuryl alcohol vapor. Thus, in the absence of other information either showing that 200 mg/cu m offers inadequate protection or showing that some other limit is more appropriate, it is recommended that the existing limit (200 mg/cu m) be continued. Research to develop a better basis for a permissible exposure limit should be conducted.

As with the present Federal limit, this limit of 200 mg/cu m is proposed as a TWA concentration. So long as the workweek is limited to 40 hours, the total dose inhaled from exposure for four 10-hour days at that concentration will not be greater than that from five 8-hour days, hence the proposal that the limit be expressed as a TWA concentration for up to a 10-hour workshift.

Many workers handle small amounts of furfuryl alcohol or work in situations in which, regardless of the amount used, there is only negligible contact with the substance. Under these conditions, it should not be necessary to comply with many of the provisions of this recommended standard that has been prepared primarily to protect workers' health under more hazardous conditions. Concern for workers' health requires that protective measures and emergency procedures be instituted below the enforceable limit to ensure that exposures stay below that limit. For these reasons, the action level has been defined as one-half the recommended TWA environmental limit, thereby delineating those work situations that do not require the expenditure of health resources for environmental and medical monitoring and for associated recordkeeping. This level has been chosen on the basis of professional judgment rather than on quantitative data that delineate nonhazardous areas from areas in which a hazard may exist. However, because of nonrespiratory hazards, such as those resulting from eye contact or skin absorption, appropriate work practices and protective measures to prevent skin and eye contact should be required regardless of the concentration of airborne furfuryl alcohol.

## (b) Sampling and Analysis

The technology is currently available to sample and to analyze furfuryl alcohol at the recommended environmental concentration limits. As discussed in Chapter III and presented in greater detail in the appendix, the use of a tube containing Porapak Q to collect furfuryl alcohol from an air sample is recommended. Elution of the Porapak Q with acetone and analysis by gas chromatography allows the determination of furfuryl alcohol over the range of 117-469 mg/cu m using a 6-liter air sample [50]. Other techniques, such as collection in a charcoal tube followed by desorption with pyridine and gas chromatographic analysis [46] or collection with a bubbler and analysis by colorimetric, spectrophotometric, or physical-chemical methods, have also been described and may be useful.

## (c) Medical Surveillance

The available information reviewed in Chapter II (Correlation of Exposure and Effect) on the toxicity of furfuryl alcohol, though limited, suggests acute upper respiratory irritation and CNS depression as possible effects. In addition, dermal penetration has been demonstrated in animals in tests indicative of similar action in humans; it seems from this and from its lipid solvent characteristics (based on its miscibility with such common lipid solvents as ethyl ether mentioned in Table IX-1) that furfuryl alcohol should also be capable of causing dermatitis. This is supported by evidence [30] that furfuryl alcohol can cause skin sensitization in tests with guinea pigs.

Inasmuch as furfuryl alcohol is not very toxic acutely and apparently is not toxic chronically to a significant degree, no requirement for frequent periodic physical examinations is proposed. Nevertheless, preplacement examinations should be required to establish a baseline with which data from subsequent examinations can be compared. Specific tests of furfuryl alcohol toxicity are not indicated by available information, so history and physical examination of structures that might be affected (eyes, upper respiratory tract, and skin) should suffice. The responsible physician should determine the frequency of periodic examinations after considering such points as the employees' exposures, work histories, and other stresses believed by the physician to be relevant.

## (d) Personal Protective Equipment and Clothing

Where there is a likelihood of skin contact with liquid furfuryl alcohol, gloves and other appropriate skin protection such as personal full-body work clothing are recommended. To minimize the risk of eye contact with liquid furfuryl alcohol, employees should wear eye protection such as safety glasses with side shields or chemical safety goggles. To prevent absorption of potentially harmful amounts of furfuryl alcohol by inhalation, respiratory protective measures may also be needed. Proper

engineering controls should be the primary means of reducing the atmospheric concentration of furfuryl alcohol in the work environment. Respirators should be used only during emergencies and nonroutine repair and maintenance activities when airborne furfuryl alcohol concentrations may not be reduced by appropriate engineering controls or administrative measures to concentrations at or below its TWA limit.

(e) Informing Employees of Hazards

At the beginning of employment, all employees should be informed of the hazards from exposure to furfuryl alcohol because of possible eye, respiratory, and skin irritations. Brochures and pamphlets may be effective as aids in informing employees of hazards. In addition, warning signs should be posted in areas of potential exposure, such as sampling points and loading and unloading facilities, and near material-handling equipment, process lines, and pumps.

A continuing education program is an important part of a preventive hygiene program for employees potentially exposed to furfuryl alcohol. A continuing education program, which includes training in the use of protective equipment, emergency procedures, and first aid, should be available to the employees. Trained persons should periodically apprise employees of possible sources of exposure to furfuryl alcohol, the potential adverse health effects associated with such exposure, the engineering controls and work practices in use to limit exposure and those being planned, and those environmental and medical monitoring procedures in use to check control procedures and to evaluate the health status of employees. Personnel potentially exposed to furfuryl alcohol or wastes associated with manufacturing, material handling, or use must be warned of the adverse effects of accidental exposure and must be informed of the signs and symptoms that may occur.

Employees should also be instructed as to their responsibilities, complementing those of their employers, in preventing effects of furfuryl alcohol on their health and in providing for their safety and that of their fellow workers. These responsibilities of employees apply primarily in the areas of sanitation and work practices, but attention should be given in all relevant areas so that employees faithfully adhere to safe procedures.

(f) Work Practices

Since adverse effects from exposure to furfuryl alcohol are possible by skin [25-27,30,32] and eye [27,28] contact and inhalation, proper work practices must be followed to prevent exposures by these routes [22,25-28,32].

Processes should be operated to minimize leaks of hazardous substances and to prevent spills during material handling, transfer, storage, and

sampling. For operations that may increase the concentration of airborne furfuryl alcohol in the work environment, adequate ventilation must be used at all times. Anyone entering the area of an accidental leak or spill must be protectively clothed to prevent accidental contacts with the skin or eyes and must wear suitable respiratory protective devices if needed.

Furfuryl alcohol will undergo violent, sometimes explosive, polymerization reactions when in contact with acids [18,19,59]. Thus, barriers or distance should separate the two substances in storage areas and, to the extent allowed by the operation, during use. If it is not known whether a specific acid or acid solution will react in an unsafe manner, the supplier or controlled tests should give needed information.

Furfuryl alcohol has a flashpoint of 75 C (167 F), so it is classified by 29 CFR 1910.106 as a combustible liquid of Class IIIA. Although at temperatures below its flashpoint furfuryl alcohol can be handled with little danger of fire, flammable vapor may be evolved at higher temperatures. Thus, smoking, open flames, or other ignition sources should be prohibited in any area where furfuryl alcohol is found.

#### (g) Monitoring and Recordkeeping Requirements

To characterize employee exposures, employers must conduct personal sampling and analysis for furfuryl alcohol. Estimates of the exposure of each employee should be made, whether or not each employee's exposure is measured. Thus, sampling strategy that allows reasonable estimates of all exposures should be employed.

Records of such monitoring should include sampling and analytical methods, times and locations of samples, whether protective devices (especially respiratory protective devices) were in use, and the exposure concentrations found or estimated. In the case of estimated concentrations, information on which the estimates were based must be included. These environmental records should be kept for 30 years, and copies of exposure data should be included with medical records to allow correlation of employees' health status with their working environment. Medical records should be kept for 30 years, since the Toxic Substances Control Act of 1976 requires that "Records of...adverse reactions to the health of employees shall be retained for thirty years from the date such reactions were first reported to or known by the person maintaining such records..." Because medical examinations will often provide the first recognized evidence of an adverse reaction, whether at the time of the examination or retrospectively, it appears consonant with this Act to require that medical records on furfuryl alcohol workers be maintained for 30 years.

## VI. RESEARCH NEEDS

Proper assessment of the toxicity of furfuryl alcohol and evaluation of its potential hazard to the working population require human epidemiologic and animal studies. Research is needed to assess the effects of long-term workplace exposure to furfuryl alcohol.

Epidemiologic studies should be performed and should consider morbidity and mortality in exposed workers with attention to possible pulmonary, skin, eye, and CNS effects. In addition, there should be investigations of possible chronic effects of furfuryl alcohol in experimental animals, the compound preferably being administered by dermal contact as well as by inhalation of vapor. These experiments should be designed and conducted so that they also give definitive information on carcinogenic potential. Additional experiments should be performed to investigate whether furfuryl alcohol can cause germinal mutations, terata, or other effects on reproduction.

There is some evidence that furfuryl alcohol is at least partially metabolized in rats to furoyl glycine, which is excreted in the urine [34]. Further research is needed on biotransformation of furfuryl alcohol and on its distribution and elimination.